NON-PROVISIONAL APPLICATION FOR UNITED STATES PATENT

FOR

OPERATIONAL STATE PRESERVATION IN THE ABSENCE OF AC POWER

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BACKGROUND

Advances in integrated circuits and microprocessor technologies have made possible the availability of computing devices, such as personal computers, with computing power that was once reserved for "main frames". As a result, increasingly computing devices, such as personal computers, are being used for a wide array of computations, and often, "important" computations.

However, computing devices, such as personal computers, are still being provided without integral backup power support. Further, unlike their server brethrens, typically, supplemental external backup power supports are seldom employed. Thus, whenever the power supply fails, these computing devices go into an un-powered state, and the system states are lost.

For those computing devices endowed with power management implemented in accordance with the Advanced Configuration and Power Interface (ACPI) (jointly developed by Hewlett Packard, Intel, et al), the computing devices are said to be in the "un-powered" G3 state.

Moreover, when power is restored, and a user presses the power button of the computing device, the user typically gets a number of messages from the operating system (OS) of the computing device. Unfortunately, many of these messages are understood by sophisticated users only. Examples of these messages include asking the user whether the user desires to boot the computing device into a safe mode, have the disk drive scanned, and so forth.

If acceptance of computing devices, such as personal computers, is to continue to expand, and the computing devices are to be used by more and more users for an increasing variety of applications, such as "entertainment"

applications, it is necessary for their usability, availability, and/or reliability to continue to improve. Thus, a need exists to improve the ability of a computing device, such as a personal computer, to handle power failures.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described by way of the accompanying drawings in which like references denote similar elements, and in which:

Figure 1 illustrates an overview of a system incorporated with the teachings of one embodiment of the present invention, including a BIOS equipped to save a persistent copy of the system state when the system suspends to memory in response to an AC absence condition;

Figure 2a illustrates the operational states of the system of **Fig. 1**, in accordance with one embodiment, including the suspended to memory state with a persistent copy of the system state saved;

Figure 2b illustrates one embodiment of the power supply of **Fig. 1** in further details, including a monitor for monitoring presence/absence of AC and a DC power source;

Figure 2c illustrates an example article having programming instructions implementing all or the relevant portions of the BIOS of **Fig. 1**, in accordance with one embodiment;

Figure 3a illustrates one embodiment of the relevant operation flow of the system to suspend the system to memory in responding to an AC absence condition, while operating in an active state, including the BIOS intervening to save a persistent copy of the system state;

Figure 3b illustrates one embodiment of the relevant operation flow of the system in responding to an AC absence condition, while BIOS is saving a persistent copy of the system state as part of a suspend process initiated due to a reason other than AC absence;

Figure 3c illustrates one embodiment of the relevant operation flow of the system in responding to an AC absence condition, while the system is suspended to memory due to a reason other than AC absence;

Figure 4 illustrates one embodiment of the relevant operation flow of the system to resume the system in an active state, in responding to an AC re-presence condition, while operating from the backup power source in a suspended to memory state; and

Figure 5 illustrates one embodiment of the relevant operation flow of the system to cold start and reset the system to an active state, in responding to an AC re-presence condition, while operating in an un-powered state, including conversion to a resume process employing the persistent copy of the saved system state if available.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of the present invention include but are not limited to method for saving a persistent copy of system state of a system when AC fails, BIOS equipped to facilitate practice of the method, power supply equipped to signal AC failure, and components, circuit boards or devices endowed with all or portions of the BIOS and the power supply.

In the following description, various aspects of embodiments of the present invention will be described. However, it will be apparent to those skilled in the art that other embodiments may be practiced with only some or all of the described aspects. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the embodiments. However, it will be apparent to one skilled in the art that other embodiments may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the description.

Various operations will be described as multiple discrete operations in turn, in a manner that is most helpful in understanding the embodiments, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

Referring now to **Fig. 1** wherein an overview of a system incorporated with the teachings of one embodiment of the present invention is illustrated. For the embodiment, system **100** includes processor **102**, non-volatile memory **104**, memory **106**, controller/bus bridge **108**, persistent storage **110**, other I/O devices **112**, buses **114a-114b**, and power supply **116**, coupled to each other as shown. Controller/bus bridge **108** will also be referred to as memory and I/O controller/bus bridge, or MCH/ICH/BB.

Processor **102** includes in particular a terminal (e.g. a pin) to receive an interrupt **134**. Non-volatile memory **104** includes in particular basic input/output system (BIOS) **124** equipped with the teachings an embodiment of the present invention. Memory **106** includes a working copy of operating system (OS) **126** and system state including applications and data **128a**. OS **126** is equipped to initiate a suspend process to cause system **100** to go into a "suspended to memory" state.

MCH/ICH/BB **108** is equipped to interrupt processor **102**, when system **100** is in an active state and an AC failed or absent condition arises. More specifically, for the embodiment, the interrupt is issued by the ICH portion of MCH/ICH/BB **108**. MCH/ICH/BB **108** further includes in particular register **122** to facilitate OS **126** to cause system **100** to go into the "suspended to memory" state. Further, MCH/ICH/BB **108** is equipped to shut off delivery of "normal" power (leaving only standby power) to cause system **100** to go into a "suspended to memory" state. MCH/ICH/BB **108** is also equipped to process device wake events, including a notification of AC re-presence while system **100** is in a suspended to memory state. In particular, MCH/ICH/BB **108** is equipped to allow resumption of delivery of "normal" power, initiate waking of system **100**, and

facilitate BIOS to initiate a resume process. Similarly, for the embodiment, processing of device wake events is performed at the ICH portion MCH/ICH/BB **108**. [AC = Alternating Current.]

Power supply **116** includes integral backup DC power source **132**, to source power for system **100** while system **100** is in an AC failed or absent condition, and a monitor **130** equipped to signal **136** presence or absence of AC power at power supply **116**. An example of integral backup DC power source **132** is a battery. For the purpose of present application, the terms "AC failed", "AC absent" and other variants should be considered synonymous, unless the context clearly indicates to the contrary. Hereinafter, integral backup DC power source **132** may also be simply referred to as either backup power source or DC power source. Further, in alternate embodiments backup power source may be a non-DC power source. [DC = Direct Current.]

Persistent storage **110** is employed to store, among other things, a persistent copy of system state including applications and data **128b** when system **100** goes into the "suspended to memory" state. The term "system state" as used herein includes OS and application states and data.

Resultantly, system **100** may be advantageously maintained in a "suspended to memory" state (by the DC power source) for at least a critical period, even when AC power is lost, to allow a persistent copy of the system state to be saved. Further, system **100** may be smoothly brought back to the saved system state, when AC power returns.

Thus, system **100** may offer its user, usability experience that is similar to that of conventional consumer electronic devices, such as televisions. For example, from the user's perspective, a television "remembers" the last channel the television was tuned to, and is powered on tuning to the particular channel.

By virtue of the teachings incorporated, embodiments of system **100** may likewise exhibit the same "remembering" behavior, turning on to its last state, after it has been "turned off", from the user's perspective.

Still referring to **Fig. 1**, except for teachings of embodiments of the present invention incorporated, processor **102**, non-volatile memory **104**, memory **106**, MCH/ICH/BB **108**, persistent storage **110**, I/O devices **112**, and buses **114a-114b** all represent corresponding broad ranges of these elements. In particular, an example of an I/O device is a networking interface. Similarly, except for the teachings of an embodiment of the present invention incorporated, BIOS **124** and OS **126** also represent corresponding broad ranges of the elements.

Various embodiments of these teachings incorporated in BIOS **124**, power supply **116**, the operational states and various operational flows of system **100**, as well as the manner these elements cooperate to provide the improvement will be described in turn below.

In various embodiments, system **100** may be a desktop computer, a set-top box, an entertainment control console, a video recorder, a video player or other processor based devices of the like.

Further, alternate embodiments may be practiced without some of the enumerated elements or with other elements. In particular, alternate embodiments may be practiced without DC power source **132** being an integral part of system **100**. That is, for these embodiments, DC power is provided from a source external to system **100**.

Figure 2a illustrates one embodiment of the operational states of system **100**. For ease of understanding, the operational states will be described assuming system **100** also includes implementation of ACPI, and mapped to the

ACPI states. For the embodiment, the operational states of system **100** include three major operational states, active state (ACPI S0 or simply, S0) **202**, suspended state (ACPI S3 or simply, S3) **204** and un-powered state (ACPI G3 or simply G3) **206**. However, alternate embodiments may be practiced without mapping to ACPI states or implementation of ACPI. For further information on ACPI including ACPI states, see The ACPI Specification, Revision 2.0b.

Within active state (S0) **202**, system **100** may be in "visual on" state **212**, or "visual off" state **214**. While system **100** is in "visual on" state **212**, user perceptible indications of system activity may be selectively activated as appropriate, including but are not limited to display devices, light emitting diodes (LEDs), speakers, and so forth. On the other end, while system **100** is in "visual off" state **214**, all visual and aural elements of system **100** are "off", giving a user the impression that system **100** has been "turned off". As illustrated, system **100** may transition between "visual on" state **212** and "visual off" state **214** based at least in part on power button (PB) events **222**.

Having visual "on" and "off" states **212** and **214** within active state (S0) **202** is a non-essential aspect of the disclosed embodiments of the present invention. The feature is the subject matter of co-pending U.S. Patent Application, number <to be inserted>, entitled <insert title>, and filed on mm/dd/yy. For further details, see the co-pending application.

Still referring to **Fig. 2a**, for the embodiment, within suspended state (S3) **204**, system **100** may be in "suspended to memory" state **216** or "suspended to memory with a persistent copy of the system state saved" state **218**. System **100** may enter into "suspended to memory" state **216** from either "visual on" state **202** or "visual off" state **204**, due to e.g. "inactivity", user instruction, or an "AC failure" condition, **224** and **226**. System **100** is considered to be in the "AC failure"

condition, whenever AC is not present at power supply **116**. Further, by virtue of the teachings provided, system **100** automatically saves a persistent copy of the then system state, and enters into "suspended to memory with a persistent copy of the system state saved" state **218**.

For the embodiment, the system state saving process may be interrupted, e.g. by the resumption of AC power. As will be described in more detail below, the system state saving process is "aborted", and the suspend process is allowed to proceed to completion (first portion of transition **240**), resulting in system **100** entering suspended to memory state **216**. At which time, system **100** immediately transitions back to visual off state **214**, (remaining portion of transition **240**).

From "suspended to memory with a persistent copy of the system state saved" state **218**, system **100** may enter un-powered state (G3) **206** if the integral DC power source is shut off or exhausted **230**. Shutting the DC power source off after a time period to prevent it from being exhausted is also not an essential aspect of the disclosed embodiments of the present invention. The feature is the subject matter of co-pending U.S. Patent Application, number <to be inserted>, entitled "Automatic Shut Off of DC Power Source in the Extended Absence of AC Power", and filed contemporaneously. For further details, see the co-pending application.

From "suspended to memory with a persistent copy of the system state saved" state **218**, system **100** may transition back to either "visual on" state **212** or "visual off" state **214** in response to AC re-present in system **100** or a power button/device wake event **232/234** if AC is present (state **218** was entered due to inactivity). In various embodiments, the latter transitions are permitted only if AC

is present at power supply **116** (state **218** was entered due to inactivity), else the power button or device wake events are suppressed or ignored.

Suppressing or ignoring power button and device wake events when AC is absent, is also not an essential aspect of the disclosed embodiments of the present invention. The feature is the subject matter of co-pending U.S. Patent Application, number <to be inserted>, entitled "Power button and Device wake events Processing Methods in the Absence of AC Power", and filed contemporaneously.

Further, system **100** returns to "visual off" state **214** if AC becomes present again while system **100** is in "un-powered" state (G3) **206**.

Referring now to **Fig. 2b**, wherein one embodiment of power supply **116** is illustrated. As shown, for the embodiment, power supply **116** includes integral backup DC power source **132** and monitor **130** as described earlier. Additionally, power supply **116** includes multiple power outputs (also referred to as power rails) **244** . The elements are coupled to each other as shown.

Accordingly, power outputs **244** may continue to supply power to elements of system **100**, drawing on integral DC power source **132**, in the absence of AC at power supply **116**. Further, monitor **130** is able to output a signal denoting whether AC is present or absent at power supply **116** at any point in time.

In various embodiments, DC power source **132** may be a battery. Monitor **130** may be implemented employing a diode and RC coupled to a comparator to provide signal **136**. Further, a logical "1" of signal **136** denotes AC present at power supply **116**, whereas a logical "0" of signal **136** denotes AC absent at power supply **116**.

In various embodiments, power outputs **244** may include normal and standby power outputs. Normal power outputs may include +12v, +5v, +3v, and -12v, whereas standby power output may include +5v. Further, normal power outputs or its delivery may be turned off.

Figure 2c illustrates an example article having programming instructions implementing all or the relevant portions of BIOS **124** of **Fig. 1**, in accordance with one embodiment. As illustrated, article **250** includes a storage medium **252** and programming instructions **252** implementing all or the relevant portions of BIOS **124** of **Fig. 1**. As alluded to earlier and to be described in more detail below, BIOS **124** includes teachings of one embodiment of the present invention to facilitate preservation of operational state of system **100** when it is in an "AC failed" condition.

For the embodiment, article **250** may be a diskette. In alternate embodiments, article **250** may be a compact disk (CD), a digital versatile disk (DVD), a tape, a compact Flash, or other removable storage device of the like, as well as a mass storage device, such as a hard disk drive, accessible for downloading all or the relevant portions of BIOS **124** via e.g. a networking connection.

Figure 3a illustrates one embodiment of the relevant operation flow of system **100** to suspend system **100** in memory in responding to an AC failure condition, while operating in active state **202**.

As illustrated, while operating in active state **202**, power supply **116** monitors for AC presence or absence, and outputs a signal to denote AC presence or absence accordingly, block **302**. In alternate embodiments, the

monitoring and signaling of AC presence or absence at power supply **116** may be performed by another element other than power supply **116**. Regardless, the monitoring and signaling continues as long as AC is present at power supply **116**.

However, when AC fails or absents from power supply **116**, and monitor **130** outputs a signal so denoting, for the embodiment, MCH/ICH/BB **108** asserts an interrupt, notifying processor **102** of the AC failure or absence condition, block **304**. For the purpose of this application, the terms "AC failure" and "AC absent" are synonymous. In various embodiments, as described earlier, the interrupt is asserted by the ICH portion of MCH/ICH/BB **108**.

For the embodiment, in response to the interrupt, processor **102** switches execution to a portion of OS **126** (interrupt handler), which responds by initiating a suspend to memory process, block **306**. More specifically, OS **126** attempts to write to register **122** of MCH/ICH/BB **108** to cause MCH/ICH/BB **108** to shut off delivery of the normal power outputs of power supply **116**, and make available only the standby power output for a small number of elements, such as memory **106**.

For the embodiment, system **100** is equipped, and initialized to generate an interrupt to transfer control to a designated interrupt handler of BIOS **124** in response to the OS write. In various implementations, the interrupt may be the unmaskable System Management Interrupt (SMI).

Accordingly, for the embodiment, BIOS **124** is able to intervene in the suspend to memory process, and save a persistent copy of the then system state in a persistent storage device, such as a hard disk drive, block **308**. Upon saving the persistent copy of the then system state in a persistent storage device, BIOS **124** completes the OS write to register **122** of MCH/ICH/BB **108**, block **308**.

In one embodiment where automatic shut off of backup power source **132** after a period of time is supported, in block **308**, BIOS **124** also sets up an arrangement to subsequently shut off backup power source **132** after elapse of the time period, before completing the OS write to register **122** of MCH/ICH/BB **108**. See copending application <insert number> for further details.

As described earlier, the action of writing to register **122** causes delivery of the normal power outputs of power supply **116** to be shut off by MCH/ICH/BB **108**, and leaving only delivery of the standby power output for a small number of elements, such as memory **106**, block **310**.

Thus, in response to the OS initiation to place system **100** in the "suspended to memory" state **216**, system **100** is advantageously placed in the "suspended to memory with a persistent copy of the system state saved" state **218** instead. System **100** may later be smoothly brought back to an active state when AC power returns.

Still referring to **Fig. 3a**, additionally, as described earlier, BIOS **124** may be interrupted while saving a persistent copy of the system state, e.g. by the resumption of AC power. At such time, for the embodiment, BIOS **124** "aborts" the saving operation, and proceeds immediately to complete the suspend process, block **308**, resulting in system **100** entering suspended to memory state **216** (first portion of transition **240**).

At which time, system **100** immediately transitions back to visual off state **214** (remaining portion of transition **240**). This process is similar to the process to be described later referencing **Fig. 4**, for transitioning from suspended state **218** to visual off state **214**.

Referring now to **Fig. 3b** and **3c**, additionally, AC failure or absence may also occur while BIOS **124** is saving the persistent copy of the system state, or after BIOS **124** has completed the saving process, and system **100** is in "suspended" state **218**. The saving process is part of a suspend process initiated due to a reason other than AC failure, e.g. inactivity. **Fig. 3a-3b** illustrate one embodiment each of the relevant operation flow of system **100** in responding to an AC failure condition arisen under each of the foregoing described situations respectively.

As illustrated in **Fig. 3b**, for the former case (i.e. AC failure while BIOS **124** is saving a persistent copy of the system state as part of a suspend process initiated due to a reason other than AC failure), notwithstanding the signaling of the AC failure condition, block **322**, BIOS **124** proceeds to complete the saving of the persistent copy of the system state, and thereafter, continues the suspend process, block **324**. Note that at this point in time, system **100** is powered by backup power source **132**.

Next, MCH/ICH/BB **108** shuts off delivery of normal power, leaving only standby power, thereby placing system **100** in suspended state **218**, as described earlier, block **326**. However, MCH/ICH/BB **108** immediately re-enables delivery of normal power, and initiates waking of system **100**, block **326**.

In response, BIOS **124** initiates hardware elements and a resume process, using e.g. a resume vector previously set up by OS **126**, block **328**.

At block **330**, OS **126** completes the resume process. However, OS immediately re-initiates another suspend process, in view of the AC failure condition, leading to the process earlier described referencing **Fig. 3a** being performed.

Figur 3c illustrates one embodiment of the relevant operation flow of system **100** (equipped with the shut off feature) in responding to an AC failure condition arisen while system **100** is in suspended state **218**.

As illustrated in **Fig. 3c**, for the latter case (i.e. AC failure after BIOS **124** has completed saving a persistent copy of the system state as part of a suspend process initiated due to a reason other than AC failure), when AC re-presence is signaled, block **342**, MCH/ICH/BB **108** resumes delivery of normal power, and initiates a system wake process, block **344**.

In response, similar to the process of **Fig. 3b**, BIOS **124** initiates hardware elements and a resume process, block **346**. Thereafter, at block **348**, OS completes the resume process as described earlier. However, OS immediately re-initiates another suspend process, in view of the AC failure condition, leading to the process earlier described referencing **Fig. 3a** being performed.

Each of the foregoing embodiments of **Fig. 3b** and **3c** (for responding to AC absence when BIOS **124** is saving or has completed saving a persistent copy of the system state as part of a suspend process initiated due to e.g. inactivity) has been described employing an approach that resumes to OS **126** to re-initiate another suspend process. However, alternate embodiment may be practiced without resuming to OS **126**. For example, BIOS **124** may be further equipped to maintain sufficient information to recognize that system **100** is being awaken because AC failed when BIOS **124** was saving or had completed saving a persistent copy of the system state as part of a suspend process initiated due to e.g. inactivity. Moreover, BIOS **124** is further equipped to proceed to perform the operations it normally performs (as earlier described referencing **Fig. 3a**) during a suspend process initiated due to AC failure, upon so recognizing the cause for system **100** being awaken.

Figure 4 illustrates the relevant operation flow of system **100** to resume system **100** into an active state, in responding to an AC re-presence condition, while operating from the DC power source in suspended state **218**. Recall from earlier description, for the embodiment, suspended state **218** is the "suspended to memory with a persistent copy of the system state saved" state.

As illustrated, for the embodiment, while operating from the DC power source **132** in "suspended to memory with a persistent copy of the system state saved" state **218**, power supply **116** monitors for AC presence or absence, and outputs a signal to denote AC presence or absence accordingly, block **402**. Again, as described earlier, in alternate embodiments, the monitoring and signaling of AC presence or absence at power supply **116** may be performed by another element other than power supply **116**. Regardless, the monitoring and signaling continues as long as AC is absent at power supply **116**.

However, when AC is re-present at power supply **116**, and monitor **130** outputs signal **136** so denoting. For the embodiment, MCH/ICH/BB **108** responds to signal **136** as a device wake event, re-enabling delivery of normal power outputs of power supply **116** to elements of system **100**, and then transfers control to BIOS **124**, block **404**. As described earlier, in various embodiments, the device wake event is processed by the ICH portion of MCH/ICH/BB **108**.

At block **406**, BIOS **124** performs various initializations of hardware elements as appropriate, and transfers control to a resume vector previously set up by OS **126** (as part of the suspend to memory process). For embodiments with the backup power shut off feature, BIOS **124** may also additionally cancel any scheduled shut off.

At block **408**, OS **126** completes the resume process, and system **100** continues operation, starting from the previously suspended system state in memory **106**.

Figure 5 illustrates the relevant operation flow of system **100** in responding to an AC re-presence condition, while operating in un-powered state (G3) **206**. For the embodiment, when AC is re-present at power supply **116**, the event causes a cold start reset for system **100**. Accordingly, BIOS **124** is given control, and it starts the cold start process to initialize various hardware elements. As part of the cold start process, BIOS **124** determines whether a persistent copy of the system state exists, block **502**.

If a persistent copy of the system state exists, BIOS **124** copies the persistent copy of the system state into memory **106**, block **504**. BIOS **124** then continues with operations similar to the operations performed under a resume process, resulting in OS **126** completing the resume process, and system **100** continues operation, starting from the restored system state in memory **106**, block **506**.

However, if a persistent copy of the system state is not found, BIOS **124** continues with the cold start process, performing various initializations of hardware elements, and then transfers to OS **126**, block **508**. At such time, OS **126** completes the cold start process, and system **100** continues operation, starting from a new system state in memory **106**, block **510**.

Thus, it can be seen from the above description, a method to preserve operational state in the absence of AC has been described. In particular, embodiments of system **100** may be maintained in a suspended-to-memory state

from a DC power source, for at least a period, during AC absence, sufficient to allow the persistent copy of the system state to be made. As a result, embodiments of system **100** may be returned to the system state saved when AC is returned.

As described earlier, the feature is particularly useful in offering the user of a computing device, usability experience that is more similar to conventional consumer electronic devices, such as a television.

While the present invention has been described in terms of the foregoing embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. Other embodiments may be practiced with modification and alteration within the spirit and scope of the appended claims. Accordingly, the description is to be regarded as illustrative instead of restrictive.